

PETERSON

The Morphology of the Head
& Mouth-Parts of Thysanoptera

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THE MORPHOLOGY OF THE HEAD AND MOUTH-
PARTS OF THYSANOPTERA

BY

ALVAH PETERSON

B. S. Knox College, 1911

THESIS

Submitted in Partial Fulfillment of the Requirements for the

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Alvah Peterson

ENTITLED The Morphology of the Head and Mouth-parts of
Thysanoptera

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Master of Science in Entomology

Justus W. Folsom

In Charge of Major Work

Stephen A. Forbes

Head of Department

Recommendation concurred in:

} Committee
on
Final Examination



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I. PREFACE

Within the order Thysanoptera striking variations occur in respect to the mouth-parts. The mouth parts of Thysanoptera are asymmetrical. I was impressed with this unique variation and was thus led to look up the literature concerning the mouth-parts of Thysanoptera. Of all the available literature at the State Natural History Library of the University of Illinois, the two following papers proved to be the most important. (1) "The Mouth-parts of the Thysanoptera," H. Garman (1890). *Bul. of the Essex Institute*, Vol. 22, p-24. (2) "On the Homologies and Mechanism of the Mouth-parts of Hemiptera," F. Muir and J. C. Kershaw, (1911), *Psyche*, Vol. 18, p-1.

H. Garman made his observations on the mouth-parts of *Limothrips cerealium* Haliday, a form belonging to the suborder Terebrantia and on these observations decided that the asymmetrical piercing organ was a mandible, while F. Muir and J. C. Kershaw worked on a form belonging to the suborder Tubulifera and decided that the asymmetrical piercing organ was a portion of the maxilla. On account of this difference of opinion concerning the asymmetrical parts in the two suborders I felt that more work needed to be done on the subject. At the outset I felt as I now feel, that such a morphological difference between two closely related suborders was highly improbable. Of the two interpretations given by the workers one must be wrong or possibly both wrong. At the beginning then, my problem was to homologize, if possible, the asymmetrical parts of the two suborders.

This phase of my work has proved to be of great interest. However, now that I have taken up a portion of the ectal morphology of Thysanoptera I do not expect to be satisfied until I have completed a comparative morphological study of the entire skeleton of the two suborders of Thysanoptera, and from such observations I hope to be able to get a little light on the relation of Thysanoptera to other insects. Thus far, only in part have I completed the task set before me. Consequently in this preliminary report I will only give observations and conclusions such as I feel comparatively sure of. I will not attempt to draw any conclusions as to the relation of Thysanoptera to other insects for I feel that I will only be justified in so doing when all the possible observations have been made. In this report only a comparative study of the head and mouth-parts of the two suborders will be given. The title of the paper indicates its content.

II. METHODS

Three plants of *Yucca filamentosa* were transplanted to the laboratory and kept well stocked with *Cephalothrips yuccae* so that whenever living material of this species was desired it was at hand. One may secure living material thruout the winter, however, from the green host plant even tho the plant may be covered with snow. At least this was true with *Cephalothrips yuccae* found on the yucca plant and *Anthothrips verbasci* found

on mullein. *Heliothrip's haemorrhoidalis* and *Thrips tabasci* were found in the city and university green houses.

To preserve Thysanoptera for stock purposes, it is best to kill them with boiling water and then keep them in 70 per cent alcohol. The material used for dissection was killed in a hot solution of potassium hydroxide, 10 per cent, and boiled for fifteen minutes or so and then reboiled in water and finally preserved in 70 per cent alcohol. This treatment puts the material into very good shape when only the chitinized parts are desired.

The use of a Leitz binocular microscope made possible the dissection of the minute mouth-parts. On trying a number of media in which parts might be dissected, carbo-aniline oil proved to be the best. Its good qualities are that it evaporates very slowly and it will clear material from any grade of alcohol above 50 per cent and also if it is desirable to stain with safranin or orange G. the same dissolved in 95 per cent alcohol, may be readily mixed with the carbo-aniline oil.

Staining my dissection material with safranin proved to be very useful in bringing out the almost colorless mouth-parts in the three species of *Terebrantia* studied. In using aniline oil in any form one precaution must be observed and that is, that as much as possible of the oil should be removed before mounting. This may be done with a blotter or dry rag or by substituting carbo-xylene or xylene before mounting. If the oil is not removed the medium in which the parts are immersed will darken eventually. In preparing Thysanoptera for sectioning purposes the following fixing agent proved to be very effect-

ive; 35 per cent solution of alcohol saturated with mercuric chloride and containing 2 per cent glacial acetic acid. This solution was poured on living material in a hot condition 80 degrees C. and allowed to act on the same for five to seven minutes. The thrips were then thoroly washed in water for twenty-four hours and then preserved in 70 per cent alcohol until ready for use. Paraffin of a melting point of 54 degrees C. proved to be a sufficiently firm medium in which to make sections as thin as five micra. Plenty of time should be given in the paraffin bath to allow the paraffin to thoroly infiltrate all parts of the body. (30-45 minutes). In staining sections Ehrlich's haematoxylin was used. For counter staining either orange G. or safranin was used. The haematoxylin stains the protoplasmic material while the orange G. or safranin stains the chitinous structures.

III. ACKNOWLEDGMENTS

This investigation was carried on under the supervision of Dr. J. W. Folsom and to him I am greatly indebted for many valuable suggestions. To Dr. A. D. MacGillivray, I also owe many thanks for his sincere interest in the work. Dr. A. F. Shull of the University of Michigan kindly furnished me with an abundance of *Euthrips tritici* which aided very materially in corroborating observations in the suborder of Terebrantia.

IV. INTRODUCTION

Thrips belong to the order Thysanoptera. The insects are very small, averaging about two millimeters in length. When the wings are present they are four in number and similar in form and with at most two longitudinal veins and only rarely with cross veins. The wings are fringed with long hairs and when at rest they are laid horizontally along the back. The mouth-parts are used for piercing and sucking. In the mouth-cone two triangular, flat, maxillary sclerites may be seen and each is furnished with a palpus. The tarsi are two jointed, bladder-like at the tips and without claws. Thrips are considered as having incomplete metamorphosis but they pass thru a semi-pupal stage.

The order Thysanoptera is divided into two suborders; Terebrantia and Tubulifera, the distinguishing characters of which are as follows, according to W. E. Hinds:

In Terebrantia the female has a saw-like ovipositor. The terminal segment of the abdomen of the female is conical, while that of male rarely like female but usually bluntly rounded. Forewings have at least one longitudinal vein reaching from the base to the tip of the wing.

In Tubulifera the female has no ovipositor. The terminal segment is tubular in both sexes. Both pairs of wings are similar in structure and have only one median longitudinal vein and this only partially developed and never reaching to the tip of the wing.

For my work during the past school year I have been able to secure only seven species of thrips, and only five of these in numbers sufficient for detailed study. Of these five species, two, *Anthothrips verbasci* Osborn and *Cephalothrips yuccae* Hinds, belong to the suborder *Tubulifera* while *Euthrips tritici* Fitch, *Thrips tabaci* Lindeman and *Heliothrips haemorrhoidalis* Bouche belong to *Terebrantia*. The above were readily identified by the use of "Contribution to a Monograph of the Insects of the order Thysanoptera Inhabiting North America" by W. E. Hinds, published in the Proceedings of the United States National Museum, Vol. 29, Page 79, (1903). As will be noted I have made figures from only two of these species. As a representative of the suborder *Terebrantia* I have used *Heliothrips haemorrhoidalis* and for the suborder *Tubulifera*, *Cephalothrips yuccae*; these two species being very typical of the two suborders. The principle reason for using these particular species was on account of the abundance of living material thruout the school year. *Cephalothrips yuccae* was found living in abundance thruout the winter on its host plant *Yucca filamentosa* while *Heliothrips haemorrhoidalis*, the common greenhouse pest, could be found in the city greenhouses at almost any time. For a description of species used in this investigation refer to W. E. Hinds.

At this point a discussion of the general position of the two suborders should be considered. It is conceded by most workers that of the two suborders, *Terebrantia* is the most generalized. All female *Terebrantia* possess a saw-like ovipositor which is a generalized characteristic of insects. In the development

of various parts of the ectal skeleton a greater degree of specialization can be seen in the species of *Tubulifera*. This is especially true in regard to the excessive development of the paired, piercing organs of the mouth.

In this introduction no attempt will be made to discuss in full the problems of this paper. I wish simply to mention that in the following pages I have described and compared in detail the head and mouth-parts of the two species figured, and an attempt has been made to settle the relation existing between the two suborders in respect to the asymmetrical parts even tho my observations have only been on a very limited number of thrips. For the discussion of this particular phase of this investigation see remarks under the following heading: Internal Head-skeleton, Maxillae, Mandibles and Conclusions. Of the described mouth-parts particular attention has been given to the structure and function of the pharynx. In the description of the two forms used as types of the two suborders, detailed comparisons will be made. In comparing the fixed parts of the head I will describe the *Tubulifera* first and compare them with *Terebrantia* while as regards movable parts it has been found more convenient to describe the species of *Terebrantia* first.

V. FIXED PARTS OF THE HEAD

Head-capsule of Thysanoptera. - In the order Thysanoptera the gross arrangement of the head and mouth structure is homolo-

gous with the gross arrangement of the head and mouth structures of a generalized homopteron (Fig. 3, C and D). The mouth parts, which form a short projecting cone, are located just in front of or between the prothoracic legs and attached to the caudo-ventral portion of the head-capsule; while the antennae are located at the extreme cephalic end of the head between the compound eyes (Fig. 1,2,A. and B.). In these characters we see the homology between the head and mouth parts of a thrips and those of a generalized homopterous insect.

Head structures in thrips differ in many respects from those of a generalized insect. In the head-capsule of a thrips almost all of the sclerites are completely united and there are no traces of sutures to show where the union has taken place. On account of this union of the sclerites one can designate only in a general way the various external areas of the skull. The areas on the sides of the head between the compound eyes and the caudal arm-like projections are the genae (g.) while the dorsal region of the head between the compound eyes and the caudal margin is the (o) occiput. The region about the antennae and between the compound eyes is the vertex (vt) and the entire ventral area of the head that is not otherwise designated is the front (fr). At the caudo-ventral margin of the head is attached an asymmetrical clypeus which terminates in a small, convex labrum. Another characteristic of the head is its elongation cephalad; this is in some forms very marked causing the genae, occiput and front to be very greatly enlarged.

Head-capsule of *Cephalothrips yuccae*, Hinds, (Pl-1, Fig. 1, 2 and 3). The head-capsule of *C. yuccae*, belonging to suborder Tubulifera, is elongated and somewhat depressed and has the same general brown color as the thorax and abdomen. The head is about one third longer than wide (Fig. 2) and about two thirds as wide as the prothorax. In a ventral aspect of the head no sutures, outside of the fronto-clypeal (f.c.) and clypeo-labral, (c.l.) are visible. Some thirty or more setae are arranged more or less definitely in pairs in respect to the meson. In *C. yuccae* a very slight asymmetry exists in the head-capsule where the clypeus and mouth-parts attach themselves to the head-capsule. In (Fig. 1) it can be seen that the left latero-cephalic corner of the clypeus is a little more cephalad than the right latero-cephalic corner. On the ventro-ectal surface (fr.) of the head very small indentations or invaginations (i) occur by which one can locate the conical projections (q) that are prominent on the ental surface. These conical projections will be described later.

In a lateral aspect of the head one can see a distinct arm-like, caudal elongation (c.a.) of the head-capsule which terminates in an acetabulum. This acetabulum fits against a small sclerite (p.s.) that occurs on the ventro-lateral surface of the prothorax. By means of this structural arrangement the insect can move its head in a dorso-ventral direction As a matter of fact in living active specimens this dorso-ventral motion is constantly taking place. At the extreme end of the caudal arms distinct invaginations can be seen on the ectal surface. On the lateral as-

pects of the head just dorsad of the caudal projecting arms a short suture (s) extends cephalad from the caudal margin. As to the homology of this suture nothing definite can be said.

On the dorsal aspect of the head another suture (s) may be seen near the caudal margin. This suture cuts off a narrow strip at the caudal margin and its two ends terminate on the margin in the two dorso-caudo-lateral areas. On the lateral ends of this strip two depressions are located that are similar to invaginations. In the majority of specimens examined sixteen setae are arranged on the dorsal side in more or less definite, paired positions in respect to the meson. In other words, for each seta there is a corresponding seta on the opposite side of the meson. Of these setae the postorbital setae (p.o.) are the most prominent.

Head-capsule of *Heliothrips haemorrhoidalis* (Pl-2, Fig. A, B, C and D). The head of *H. Haemorrhoidalis*, belonging to the suborder Terebrantia, differs in some structural detail from that of *C. yuccae*. The head of *H. haemorrhoidalis* is but slightly elongated. From a dorsal view (Fig. 3) the head-capsule is about one-fourth broader than long and its width is two-thirds that of the prothorax and abdomen. Almost the entire surface of the capsule is highly reticulated with chitinous, elevated thickenings comparable with the reticulations of the thorax and abdomen. On the frontal area (fr.) of the head these reticulations become very faint and disappear in the region of the vertex. In a ventral view of the head-capsule no sutures can be seen except the fronto-clypeal (f.c.) suture and the clypeo-labral suture (c.l.). Some

sixteen or more setae are found on the ventral region of the head and these are arranged in more or less definite paired positions in respect to the meson.

The caudo-ventral margin of the head capsule is decidedly asymmetrical (Fig. A). This decided asymmetry holds true for all the *Terebrantia* examined. If a transverse line is drawn from the two caudo-lateral points where the prominent reticulated structure of the capsule seems to end, a distinct asymmetrical triangle is formed. The obtuse cephalic apex of the triangle lies on the left side of the head and slightly mesad of a line running caudad from the meso-caudal angle of the compound eye. The shorter leg of the triangle is then on the left while the other leg is about twice as long and runs to the right caudo-lateral margin of the head. In most *Terebrantia*, at least in all examined, the positions of the conical projections (g), that occur on the ento-ventral surface of the head-capsule can be located on the ectal surface as two pit-like depressions (i) that lie directly caudad of the meso-caudal angles of the compound eyes. In *H. haemorrhoidalis* these invaginations (i) are very prominent and they hold the same position as those found in *C. yuccae*.

From the ventro-lateral angles of the head-capsule (Fig. C and D) there extend two caudal projections (c.a.). These projections are a part of the head-capsule and similar in position to those found in *C. yuccae*. Their lighter shade of color and their faintly, reticulated surface might lead one to think that they were a part of the mouth structures but in dissection they re-

main attached to the head when the mouth-cone is carefully removed. These projections or caudal arms (c.a.) in this particular species are decidedly asymmetrical on account of the greater degree of asymmetry of the mouth parts of this particular form. The left arm (Fig. C) is not constricted at its base and does not end in a distinct acetabulum as in *C. yuccae*, but its entire dorsal edge fits against a prothoracic sclerite. This, however, is only true when the head is retracted, for the head of *H. haemorrhoidalis* is capable of considerable extension which is made possible by a relatively large membranous area (me) existing between the head and prothorax as indicated by the solid black lines in (Fig. 8). The right caudal projecting arm (Fig. D, c.a.) is slightly smaller than the left, constricted at its base and located somewhat more dorsad. This distinct difference does not occur in all the *Terebrantia* examined but is here exaggerated on account of the more decided lateral asymmetry of the clypeus. The right caudal arms (c.a.) in *Euthrips tritici* and *Thrips tabasci* are not constricted at their base but are only smaller than the left arms. Other evidence that this decidedly constricted piece is the right caudal projection will be given when I treat of the mouth-parts. In all the species of *Terebrantia* examined a distinct invagination (i) occurs on the ectal surface of the right and left caudal arms.

In a lateral view of the head no short suture is found extending cephalad from the caudal margin of the head as in (Fig. 3) of the *C. yuccae*. The suture (s) that cuts off the caudal strip

on the dorsal side of the head (Fig. B) cannot be definitely located. Possibly the heavily chitinized, elevated, transverse line (s) near the caudal margin may represent this suture. On the strip cut off by this suture no invaginations were found. The dorsal area of the head is strongly reticulated except at the extreme cephalic and caudal margins. Some ten prominent setae are arranged in pairs in respect to the meson.

Clypeus and Labrum of *Cephalothrips yuccae* - (Pl-1, Fig. 1)

The clypeus (c) is the asymmetrical, mesal piece of the head. The labrum (lr) is the small, distinct, dark, convex piece at the apical end of the clypeus. This is the interpretation F. Muir and J. C. Kershaw give as a result of their study on a Tubulifera. I believe their interpretation to be correct. In all species examined belonging to the suborder Tubulifera, the clypeus is asymmetrical in somewhat the following manner. Using *C. yuccae* as a type of Tubulifera we see that the left latero-cephalic corner is slightly more cephalad than its right latero-cephalic corner, thus making the clypeus asymmetrical. But a more pronounced asymmetry exists on the left lateral margin near the cephalic end. In this region of the left margin occurs a distinct notch which takes up almost one-half of the distance covered by this suture. Into this notch fits the mesal knob-like protuberance of the adjacent, triangular piece, the maxilla (l.mx.). The right margin of the clypeus is not notched but is a straight line from the head capsule to the labrum. On the ectal surface of the clypeus eight setae may be found. The small, distinct, dark, convex piece at the apex of the clypeus is the labrum (lr), as before mentioned.

The structure of the labrum is of such a nature that it almost surrounds the projecting left asymmetrical mouth seta (mx.s.) The ectal surface of the labrum is convex while its ental surface is concave, thus a groove is formed thru which the left asymmetrical seta (mx.s.) may pass.

Clypeus and Labrum of *H. haemorrhoidalis* (Pl-2, Fig. A). In the suborder Terebrantia the clypeus is asymmetrical but not in exactly the same way as in Tubulifera. The clypeus (c) in *H. haemorrhoidalis* is the asymmetrical mesal piece of the mouth-cone, while the labrum (lr) is the small, distinct, convex piece at the distal end of the clypeus. H. Garman does not designate the parts of this mesal area of the mouth-cone in the above manner. But in his work on *Limothrips cerealium* Haliday, he regards the area cephalad of the double-dotted, transverse line (f) as the clypeus and everything distad of this double-dotted, transverse line as the labrum. I do not regard this double-dotted, transverse line as marking the position of a suture but rather the location of a fold as indicated by a double row of dots. This double-dotted line (f) marks the position where the heavily chitinized portion of the clypeus becomes more or less membranous (me.). Furthermore this line indicates the angle where the mouth-cone takes a ventrad direction from the general contour of the head. The area cephalad of this angle or double dotted transverse line is more or less membranous (me.) thus permitting the mouth-cone to be more or less movable. In unstained, clear, whole mounts that have been treated with potassium hydroxide this area

is very hyaline; while in whole mounts stained with safranin it takes up comparatively little stain, but sagittal sections (Pl-5, -Fig.J) thru this area, that have been stained with haematoxylin, show a decided blue color similar to the blue color of the membranous areas between the head and prothorax. The area in consideration is as thick as the area distad of the dotted line but the blue staining indicates a greater degree of protoplasmic material in this region and not as great an amount of thick, chitinous substance. The membranous portions of the ecto-skeleton are represented by black, solid lines (me.) while the chitinized head-capsule (h.c.) is represented by a double line. These same membranes occur likewise in *C. yuccae* (Pl-5, Fig.13) but are not as pronounced as in *H. haemorrhoidalis*. The mesal area distad of the double dotted line is heavily chitinized and is the clypeus proper and not the labrum as Garman would have it. The labrum (lr.) is the small, convex piece at the terminal end of the clypeus and is similar in structure to the labrum of *C. yuccae*. In H. Garman's drawing of *L. cerealium*, this small piece is clearly represented but is not designated as the entire labrum.

The asymmetry of the clypeus in *H. haemorrhoidalis* is quite different from that of *C. yuccae*. In *H. haemorrhoidalis* no distinct notch occurs on the left margin but a more pronounced asymmetry exists in respect to the corresponding cephalic extension of the right and left latero-cephalic corners of the clypeus. If the clypeus is considered as extending up to the head-capsule as in *C. yuccae*, the left latero-cephalic corner is decidedly more cephalad and mesad than its right one. The left margin of the clypeus is

almost a straight line from the labrum to the angle on the head-capsule. This line, cephalad of the double dotted line, is very hard to distinguish in this species but is more readily seen in *Euthrips tritici* and *Thrips tabasci* and especially if the whole mounts are stained with safranin. In dissecting out the mouth-parts, the clypeus (c) and the triangular sclerite (l.mx.), maxilla, to the left of the clypeus, always split apart on this line, which goes to prove that a suture really exists even tho it is hard to see. The right margin of the clypeus is not a straight line but runs in a curved line from the labrum almost to the right lateral margin of the head-capsule. This unique arrangement results in making the clypeal area very asymmetrical. This general asymmetry is well shown in H. Garman's drawing of the head of *Limothrips cerealium*. On the ectal surface of the clypeus of *H. haemorrhoidalis* six setae may be found.

Compound Eyes. - (Pl-1, Fig. 1, 2 and 3; Pl-2, Fig. A, B, C and D). The compound or faceted eyes of thrips are of a considerable size and located in the latero-cephalic areas of the head.

In *Cephalothrips yuccae* in a lateral view, the compound eyes are reniform in outline with the concave margin caudad. The eyes do not protrude beyond the general curve of the head and they extend onto the dorsal and ventral areas to a considerable extent. The surface of each eye is similar to a raspberry in being composed of an aggregation of facets that are uniform in size and not so crowded as to lose their circular outline. Among the facets on the dorsal side a few scattered setae may be found. After the removal of the internal structure of the eye a transparent cornea

remains.

The compound eye of *H. haemorrhoidalis* is likewise reniform in outline but each eye protrudes more or less from the general curve of the head. The facets of the eye are fewer in number, scattered and not uniform in size. In a dorsal view all the facets except two on the cephalic margin, are of uniform size and scattered between the facets a few setae may be located. The six, larger, opaque facets of the compound eye can all be seen in a ventral view. After removing the internal structure of the head by means of potassium hydroxide these six facets do not become clear and transparent as the others do but still retain their muddy brown color.

Ocelli. - (Pl-1, Fig. 2 and 3; Pl-2, Fig. B, C and D). There are three simple eyes on the dorsal side of the head between the compound eyes and they form a triangle with the apex forward.

The ocelli (oc.) of *Cephalothrips yuccae* are clear, circular bodies slightly larger than the facets of the compound eye. The triangle they form takes up a large share of the space between the compound eyes and this area is not elevated above the general plane of the head-capsule. The mesal ocellus is on the transverse line running between the cephalic ends of the compound eye.

The ocelli of *Heliothrips haemorrhoidalis* in a dorsal view are clear, oval bodies. The triangle formed by these ocelli is comparatively small and somewhat elevated above the head-capsule. The chitinous reticulation of this area is of a relatively finer mesh than that of the remainder of the head-capsule. About the cephalic ocellus four setae can be seen while the six most pro-

minent setae are laterad and caudad of the lateral ocelli, two being laterad and four caudad.

Internal Head-skeleton. - The internal head-skeleton will be discussed under two subheadings, Description and Discussion. Under the first subheading the various parts of the internal head-skeleton will be described. Rather than name the various portions, letters will be used to indicate the parts under consideration. Under the subheading Discussion the interpretation and homology of the parts will be considered.

Description, (Pl-3, Fig. 5,6,7 and 8; Pl-4, Fig. F). - In the head of *Cephalothrips yuccae* the internal head-skeleton is especially well developed and almost all the parts can be readily differentiated from the head-capsule and mouth-parts. By carefully teasing away the dorsal half of the head-capsule in material that has been treated with potassium hydroxide, stained and cleared, the following parts can be seen. (Pl-3, Fig. 5,6,7 and 8). The most prominent internal head structure in *C. yuccae* is a pair of long, chitinous strips (x) which extend cephalad from the apex of the mouth-cone into the region of the compound eyes. These strips run parallel with the meson and at their cephalic ends they unite in a small broadened sheet (x-1) while at their ventral end in the apex of the mouth-cone the two strips (x) converge and again unite with a broad and somewhat triangular plate (x-2). The ventral edges of this triangular plate (x-2) unite with the apical ends of the two triangular maxillary sclerites and from the dorso-lateral corners of this more or less triangular plate (x-2) two dorso-lateral, chitinized strips (x-2) extend parallel with

the lateral margins of the two, triangular, maxillary sclerites (l. mx and rt. mx) and are solidly united with the same. The triangular plate has on its cephalic aspect extensions that unite with the pharynx (See Pharynx). These connections are not figured for I have been unable to make out their real nature as yet.

At the point where the two long, mesal strips (x) unite with the triangular plate (x-2) at the apex of the mouth-cone a distinct, y-shaped, chitinized piece (Fig. 7,-y) exists. The short stub-stem of the y-shaped piece is loosely fitted between the triangular plate and the pharynx (p) while the arms are caudad of the mesal strips (x) and project dorso-laterad into the mouth-cone.

The purpose of the long, mesal pair of strips (x) seems to be to aid in guiding the exceedingly long, paired, piercing organs (m.s.) of *C. yuccae*. In sagittal sections or in lateral views of cleared, whole mounts it can be seen that as the long, paired, piercing organs begin to bend caudad in the region of the compound eyes they pass, at the cephalic end of the mesal strips, dorsad but as they approach the mouth-cone they slip along the lateral edge of the strips. The mesal strips (x) themselves near their middle are of a considerable width dorso-ventrally owing to a thin partially membranous, ventral extension. Near the apex of the mouth-cone the paired piercing organs (m.s.) are cephalad of the mesal strips and the triangular plate and they pass along the lateral extensions (Fig. 11-1.e.) from the pharynx (See Pharynx).

The foregoing head structures in *C. yuccae* are all isolated, distinct pieces in themselves while the remainder of the head structures are all almost entirely united with the head-capsule.

Possibly at this point it would be best to describe the head structures found in *Heliothrips haemorrhoidalis* that compare with those already described in *C. yuccae*. In making this comparison it is immediately noted that possibly with one exception all the above described parts are wanting in *H. haemorrhoidalis*. This is probably due to the generalized condition of *H. haemorrhoidalis*. In *H. haemorrhoidalis* the paired, piercing organs (m.s.) are not excessively developed but are relatively short and thus guides are not needed as in *C. yuccae* for these parts. However, even tho I have not as yet found parts homologous with those of *C. yuccae*, I feel that beginnings of these parts must exist in some of the more specialized Terebrantia. The one exception mentioned above is the existence in *H. haemorrhoidalis* of a piece (y) homologous in position and somewhat in structure with the y-shaped piece found in *C. yuccae*. This piece (Fig. G and I) is located on the dorsal side of the ventral end of the pharynx (p) and ends dorsally in two short, dorso-lateral extending arms, while the stem of the y-shaped piece seems to be greatly elongated.

Returning to *C. yuccae*, the portions of the internal head-skeleton which are united with the head-capsule will next be described. The following strips, bands, or chitinized thickenings (z, z-1, z-2, q, w and w-1) take up safranin stain very readily and the resulting color is not like that of the head-capsule but similar to the color of the stained internal head structures already described. By means of a stained head in an ectal or ental view, the extension of these thickenings or internal head structures is readily traced. Along the caudo-ventral margin of the head-capsule

adjacent to the mouth-cone a distinct, narrow, chitinized strip exists (z). This chitinized thickening extends onto the lateral margin of the head-capsule and branches. In *C. yuccae* there are on each side three distinct branches (z-1, z-2 and w). The central branch (z-1) is a lateral continuation of the thickening (z) and ends at the short suture (s) found on the caudo-lateral margin of the head. Of the other two branches on one side, the mesal one is the caudad extending branch, (z-2), which runs to the tip of the caudal arm and ends in an area about the invagination (i) found on the caudal arm. The third branch (w) arises laterad of the caudal branch (z-2) and extends cephalad on almost the extreme ento-lateral aspect of the head-capsule. This branch is very prominent. Its cephalic end (w-1) is greatly enlarged, hollowed out and free from the head-capsule. Into the hollowed portion fits the ball-like, proximal end of one of the paired, piercing organs (m.s.). Thus at this point a ball and socket joint exists which permits the paired, piercing organs (m.s.) to function.

Besides the chitinized thickenings just described a pair of distinct ental projections (q), conical shaped in some species, occur caudad of the meso-caudal angles of the compound eyes or meso-cephalad of the hollowed structure (w-1) into which the paired piercing organs fit. On the ectal surface at the caudal end of these projections, minute invaginations (i) exist. F. Muir and J. C. Kershaw describe these projections (q) as places where muscles attach themselves. This may be true but possibly they act also as notches into which the knobbed parts of the basal piece of the paired piercing organs (m.s.) slip when the piercing or-

gans are in use. At least in all forms studied in which the mouth-parts were extruded or on removal of the tension exerted on the paired piercing organs, the paired piercing organs (m.s.) always caught on these conical projections (g). As to how true this is under actual living conditions there is considerable question.

The caudal strip (Pl-1, Fig. 2 and 3) along the dorso-caudal margin of the head may be comparable to the thickenings thus far taken into consideration. However, this strip is distinctly bounded by a suture on its cephalic edge and also it does not stain in the same manner but stains like the head capsule. Apparently there exist on its ectal surface near its lateral ends two indentations; possibly these are invaginations.

In the *Terebrantia* the above mentioned chitinized thickenings (Pl-4, Fig. F;-z, z-1, z-2 and v) are present but are more generalized in structure. As in *C. yuccae* a distinct thickening exists along the caudo-ventral margin of the head adjacent to the mouth-cone. This thickening on the left side gives rise to three branches (z-1, z-2 and v), while on the right only two (z-1 and z-2) are present. The caudal branch is present on both sides and extends caudad on the ental surface of the caudal arms (c.a.) of the head-capsule to the point where the distinct invaginations (i) exist on the ectal surface of the caudal arms (c.a.). At this point also the paired piercing organs (m.s.) of the head arise. In a latter discussion (See Mandibles) it will be seen that the paired piercing organs (m.s.) of *H. haemorrhoidalis* are homologous with those of *C. yuccae*. As in *C. yuccae* the main thickening (z) con-

tinues as a small branch (z-1) onto the dorso-lateral portion of the head-capsule. The cephalic pair of branches (w) laterad of the caudal branches does not exist in the more generalized Thysanoptera for this is only an adaptation fitted to meet the needs of the excessively long, paired, piercing organs of *C. yuccae*. Mesad of the caudal branch on the left side a cephalic thickening exists (v); this thickening arises at the apex of the asymmetrical triangle (See description of Head-capsule) and extends forward to connect with the base of the left ental, conical projection (q) located meso-caudad of the left compound eye. This connection between the conical projection on the right side is entirely lost. As should have been mentioned before, two, distinct, conical projections (q) exist on the ental surface of the ventral side of the head-capsule opposite the invaginations (i) occurring on the ectal surface and caudad of the meso-caudal angles of the compound eyes. The caudal strip of the dorso-caudal margin of the head are in the Terebrantia less distinct than in *C. yuccae* and as far as can be seen there are no indentations on the strip comparable to those found in *C. yuccae*.

Discussion, - All the parts described in the foregoing description are parts of the internal head-skeleton even tho greatly modified. If such is the case then the various bands, strips, plates, thickenings etc. go to make up the arms of the tentorium and its parts. The homology of the tentorial structure in detail with that of other insects I have been as yet unable to establish; consequently, the names of the various parts cannot

be designated with any surety. Only in a generalized way will an attempt be made to discuss the varicus parts.

As suggested before, the presence of the pair of long mesal strips in *C. yuccae* is undoubtedly an adaptation brought about by the excessive development of the paired piercing organs (m.s.). Such an adaptation is quite essential in guiding the long somewhat flexible mouth-parts. Since in the Terebrantia the paired piercing organs are comparatively short these guiding parts are not developed. The function of the y-shaped piece (y) found in the two suborders is as yet undetermined. Turning to the chitinous thickenings existing on the caudo-ventral margin of the head the distinct difference in the two suborders exists in the cephalic branches (w and v.). In the Terebrantia the existence of the one cephalic branch (v) connecting with the left invagination is very significant if we take into consideration the fact that *H. haemorrhoidalis* is the more generalized form. This branch indicates that in still more generalized forms there existed a similar connection with the right invagination (i). These connections are altogether lost in Tubulifera but the invaginations and ental projections still exist. The cephalic paired branch (w) of Tubulifera is then not related to the single cephalic branch of Terebrantia. In Terebrantia the paired piercing organs are attached to the ental surface of the caudal arms of the head-capsule but on account of the enlarged development of these parts in *C. yuccae* their points of attachment have been pushed forward into the head-capsule and as a result the pair

of cephalic branches (w) exists.

In general, in all insects, the invaginations of the arms of the tentorium are more or less in a fixed, morphological position and usually present. In the two suborders of Thysanoptera two pairs of invaginations (i) show very plainly and possibly a third pair in *C. yuccae*. The significance of these invaginations in insects exists in the fact that certain invaginations are always associated with their respective mouth-parts. Consequently, if such invaginations can be determined then the mouth-parts with which they are associated may be interpreted. The mandibles are always associated with the invaginations of the anterior arms of the tentorium, while the maxillae are associated with the invaginations of the posterior arms. On this basis I expect to be able to reach an interpretation of the piercing organs of the mouth. In the two suborders a distinct pair of invaginations (i) exists caudad of the meso-caudal angles of the compound eyes and another pair on the ectal surface of the two caudal arms of the head-capsule. These two pairs I consider to be homologous with each other in all Thysanoptera. In *C. yuccae* a third pair of invaginations may exist on the caudo-dorsal strips of the head-capsule. As stated before, no definite conclusion has been reached in respect to the interpretation of the internal head structure and consequently I am not certain as yet of any of the invaginations. Therefore I cannot give at this point in my work a final interpretation of the mouth-parts on the basis of their relation to the internal head-skeleton.

The one conclusion that may safely be drawn is that the invaginations on the caudal arms are homologous throughout all species of thrips and the same may be said of the invaginations found on the ventral area of the head (fr.) caudad of the meso-caudal angle of the compound eye.

VI. MOVABLE PARTS OF THE HEAD

The movable parts of the head will be taken up in the following order; antennae, labium, maxillae, mandibles and pharynx. In the discussion of the various movable parts, in each case those of *Terebrantia* will be considered first and then the movable parts of *Tubulifera* will be compared with the *Terebrantia*.

Antennae. - (Pl-1, Fig. 4; Pl-2, Fig. E). The antennae of thrips are prominent and located between the compound eyes in the extreme, cephalic extension of the head (Fig. 1, 2, 3, A, B, C and D.). The location is the same as that of many homopterous forms. The spherical or cylindrical segments vary in number from six to nine. Setae and sense cones vary in size and number in the different species. Sense cones (s.c.) are spine-like, hyaline, bluntly pointed structures and may occur singly or as a forked structure. They are not found on all antennae and when present they confine themselves to certain segments 3-6

The antennae of *H. haemorrhoidalis* (Pl-2, Fig. E) are twice as long as the dorsal view of the head-capsule (Fig. B) and inserted at the extreme cephalic end of the head in the depressed area between the protruding compound eyes. Between the basal segments of the antennae a slight elevation of the head capsule occurs. The antennae consist of eight segments all of which are reticulated, except the two distal segments, with chitinous elevations corresponding to the chitinous elevations on the head. Segments three to six are more or less of a similar shape and annulated in a like manner. Each segment bears six or more distinct setae on its enlarged cephalic end. Segments one, two, six, seven and eight have a distinct brown tinge as the head-capsule, while segments three, four, and five are only slightly brown. On the cephalic end of segment four a very thin, hyaline, two-branched sense cone may be seen. No other indications of sense cones were found on the antennae of *H. haemorrhoidalis*.

The antennae of *Cephalothrips yuccae* (Pl-1, Fig. 4) are one and one-third times longer than the dorsal view of the head-capsule. The area of insertion of the antennae upon the head occupies the greater part of the space between the compound eyes. Only a small elevated area occurs between the basal segments in *C. yuccae*. The antennae are composed of eight segments all of which bear a few, short setae but only segments three, four, five and six bear a pair of simple, spine-like sense cones (s.c.). Segments two to six are of the same general size and shape, while

the basal segment and the two apical segments have a slight change of structure. The entire antennae is of a yellow color except for the two basal segments which are of a light, brown color.

Labium (Pl-5, Fig. K and 14), - The labium is the entire convex, caudal area of the mouth-cone and is no longer than the other parts of the mouth-cone. In this respect it strikingly differs from the long beak of Hemiptera. In general the labium of thrips divides itself into two very distinct areas, the submentum and mentum and at the distal end of the mentum a pair of short, segmented palpi occur and usually the extreme distal end bears two small projections. A caudal view of the labium of thrips shows that it is short, wide and triangular in outline; the apex of the triangle being at the distal end. Lateral and ventral views of the mouth-parts show the characteristic convex shape of the labium. The labium attaches itself along its lateral margins to the two triangular pieces that bear palpi (rt. mx. and l. mx.) and its dorso-lateral corners connect with the caudal arms (c.a.) of the head-capsule, while its dorsal edge connects with the prothorax by means of a membrane (me.).

The labium of *H. haemorrhoidalis* (Fig. K) corresponds to the above generalized description. On account of the elongated mouth-cone of *H. haemorrhoidalis* the dorso-ventral length of the labium is about the same as the width of the basal portion of the submentum. The mentum (m) and submentum (s.m.) are distinctly divided by a clear-cut suture (s). As indicated in (Fig. K) slight

indications of reticulations (ri.) show on the ectal surface of the labium. At the apical end of the nearly circular mentum in a light colored area, a pair of two-segmented palpi (lb.pl.) may be found and two short projections occur on the lateral apical margin. These projections are described by Hinds as paraglossae. On the labium six setae may be found - one pair on the lateral margin of the submentum and two pairs on the distal portion of the mentum.

In a like manner the labium of *C. yuccae* (Fig. 14) corresponds to the generalized description. The mouth-cone of *C. yuccae* is comparatively short in its ventral extension, consequently the dorso-ventral measurement is less than one-half the distance between the dorso-lateral angles of the submentum. The submentum (s.m.) and mentum (m.) are not entirely divided by a suture (s) for in the mesal portion of the labium the suture disappears, however, the two ends of the suture can be easily made out on the lateral margins. The labium of *C. yuccae* has no reticulations as in *H. haemorrhoidalis* but the submentum is strongly chitinized at its dorsal margins as indicated by a dotted line. As in *H. haemorrhoidalis*, at the apical end of the mentum a light area exists in which a pair of two segmented palpi occur. The two short projections at the apical margin have united in *C. yuccae* and form a lip-like structure over which the movable pair of piercing organs (m.s.) pass. This lip-like structure is indicated by shading in (Fig. 1). The arrangement of the six setae on the labium is similar to *H. haemorrhoidalis*.

Maxillae of *Heliothrips haemorrhoidalis* (Pl-2, Fig. A,C, and D; Pl-4, Fig. F). In an ecto-ventral view of the mouth-cone of *H. haemorrhoidalis* two asymmetrical, triangular pieces can be seen located laterad of the clypeus and labrum. These two irregular, triangular pieces (l.mx. and rt.mx.) bear two-segmented palpi. On comparing the position and structure of these two pieces with those of similar pieces in Hemiptera they are seen to be without question homologous with the so-called maxillary sclerites described by F. Muir and J. C. Kershaw in their work "On the Homologies and Mechanism of the Mouth-parts of Hemiptera". Included in their paper is a description of the mouth-parts of a species of Tubulifera and in this work they have described the parts under consideration as maxillary sclerites. Additional evidence is furnished in Thrips that these pieces are maxillae, in the fact that two segmented palpi occur on each, while in Hemiptera the palpi are always wanting.

In an ental view of the mouth-parts one can see a single, long, stout, piercing structure (mx.s.) arising from the region about the cephalic (proximal) end of the left maxillary sclerite (l.mx.). This structure (mx.s) has a swollen base and a distinct suture exists near its middle. This prominent mouth-part exists only on the left side, for no such enlarged organ is found on the right side. Because of this fact there is a unique asymmetry of mouth-parts in Thysanoptera. By careful observations of the relation of parts on the right side one can see at the cephalic end of the right, maxillary sclerite (rt.mx.)

an elongated diamond-shaped piece (r.mx.s.) holding the same position in respect to the right, maxillary sclerite (r.mx.), that the functional, piercing organ (mx.s.) of the left side holds in respect to the left, maxillary sclerite (l.mx.). This diamond-shaped piece (r.mx.s.) is located between the right, caudal arm (c.a.) of the head capsule and the right margin of the labrum. Furthermore, this piece is not flat and entirely in the same plane as the maxillary sclerite, but its ento-mesal end is free and projects slightly meso-caudal into the lumen of the mouth-cone. Undoubtedly this piece is homologous with the functional, piercing organ (mx.s.) found on the left side but it is very rudimentary.

H. Garman calls the single, large, piercing organ on the left side a mandible; his reason for this being that it has the relative position of a mandible in respect to the maxillary sclerite and the labrum, and also the fact that it is a very stout structure consisting of but a single piece. The last statement may have been true with *Limothrips cerealium* which he studied but in all the *Terebrantia* I have observed this piece (mx.s.) has a distinct suture dividing the swollen basal part from the needle-like, distal portion. Possibly this structure is a mandible but it has been extremely difficult to decide whether this piercing organ is connected to the head-capsule or to the maxillary sclerite. In drawing (Fig. F.) I chose from a great many dissected and mounted specimens as typical a condition as could be found. In this figure it is to be noted that the greater portion

of the basal part of the piercing organ (mx.s.) comes in contact with the base of the left maxillary sclerite. In teasing away the mouth-parts from the head-capsule the asymmetrical, piercing organ at times remains attached to the head-capsule while in as many cases it is removed from the head-capsule and apparently connected with the teased-away mouth-parts. The entire cephalic area of the basal portion of the mouth-cone is membranous (me.) (See discussion on Labrum) and on account of this characteristic it is almost impossible to determine the connection. This same difficulty was experienced with the other Terebrantia examined. On account of this difficulty I have tried to approach the interpretation of the asymmetrical piercing organ (mx.s.) from another view point. This view point, as mentioned in the discussion of the internal head-skeleton, is in respect to the association of the mouth-parts (maxillae and mandibles) with the internal head-skeleton. This will be more fully discussed at the end of the mandible paragraph. For convenience of description in this paper I have adopted the terms maxillary setae for the asymmetrical pair of piercing structures, in the two suborders. The reason for such are discussed at the end of this subheading 'Maxillae.'

Maxillae of Cephalothrips yuccae (Pl-1, Fig.3; Pl-3, Fig.5, 6, and 8). - In an ecto-ventral view of the mouth-cone of *C. yuccae* two triangular maxillary sclerites (rt.mx. and l.mx.) may be found holding the same relative position as in *H. haemorrhoidalis*. On each sclerite a two segmented palpus is borne. The two sclerites

are asymmetrical in a manner, differing considerably from that of *H. haemorrhoidalis*. At the cephalic end of the mesal margin of the left maxillary sclerite (l.mx.) a distinct, meso-extending knob exists. This knob-like enlargement fits into a notch at the cephalic end of the left, lateral margin of the clypeus (c). This unique asymmetry is characteristic of all *Tubulifera* I have examined.

In an ental view of the maxillary sclerites (Pl-3, Fig.5,6,7, and 8) the following structures may be seen. As mentioned in a discussion of the internal head-skeleton of *C. yuccae*, a distinct, triangular plate (x-2) joins the two latero-apical margins of the maxillary sclerites and also arising from the two dorso-lateral angles of this plate (x-2) is a pair of dorso-lateral extensions (x-3). These extensions are simply thickened edges of the lateral margins of the maxillary sclerites.

The asymmetrical, piercing organ in *Tubulifera* is found to correspond with the maxillary seta of *Terebrantia* in respect to position and structure. The left maxillary seta, however, is not straight as in *Terebrantia*, but its heavy basal portion is bent so as to connect with the left maxillary sclerite at a right angle. No prominent suture was noted at the point where the enlarged basal portion begins. In some specimens a suggestion of such a suture, however, seemed to be present. The functional maxillary seta in *C. yuccae* distinctly connects with the knob on the cephalic end of the mesal margin of the left maxillary sclerite (Fig.6). At the cephalic end of the mesal margin of the right maxillary sclerite a distinct, short, curved and pointed projection exists (Fig.8,r. mx.s.) which is firmly attached to the right, maxillary sclerite. This is the rudimentary, right, maxillary seta. In

dissection these two pieces (mx.s. and r. mx.s.) always remain attached to their respective maxillary sclerites. On account of this firm connection in this suborder it certainly appears that the so-called maxillary setae are portions of the maxillae and not mandibles as H. Garman would have the maxillary seta in *Limothrips cerealium*.

F. Muir and J. C. Yershew in their work on a *Tubulifera* interpret the asymmetrical parts (mx.s.) as portions of the maxillae. They use two principle lines of evidence. In the first place the asymmetrical parts are firmly attached to the maxillary sclerites, which is true, and second, they have proved to their own satisfaction that the paired, piercing organs (m.s.) are mandibles, consequently, the remaining, asymmetrical pair of piercing organs are parts of the maxillae. Personally I cannot see the force of their argument which seems to prove that the paired, piercing organs are mandibles. However, I am ready to grant that if one pair of the piercing organs is satisfactorily interpreted as mandibles the other pair must be maxillae or portions of them.

On the above evidence we see that the asymmetrical, piercing organs (mx.s.) in the two suborders are homologous in respect to structure and position. Thus far in the investigation I have not found conclusive evidence that will prove that the asymmetrical, piercing organ is a mandible as H. Garman would have it or a portion of the maxillae, as F. Muir and J. C. Yershaw interpret it. Consequently, a proved interpretation cannot be given

at this point but since it has been shown that in the two sub-orders the asymmetrical, piercing organs are homologous, one or the other of the interpretations is correct or perhaps both are wrong. I have adopted F. Muir and J. C. Kershaw's interpretation of maxillary seta (mx.s.) for the functional, left, asymmetrical, piercing organ of both suborders. This has been done to emphasize the homology in the two suborders and also as an aid in description and reference. F. Muir and J. C. Kershaw's interpretation is used, because on the whole I think their interpretation is backed by more conclusive evidence than the interpretation of H. Garman. In other words, F. Muir and J. C. Kershaw's interpretation which is based on observations on a Tubulifera can be used in interpreting the parts in Terebrantia, while H. Garman's interpretation which is based on a Terebrantia cannot be as naturally applied to a Tubulifera.

Mandibles of *Heliothrips haemorrhoidalis* and *Cephalothrips yuccae* (Pl-1, Fig. 3; Pl-2, Fig. C and D; Pl-3, Fig. 5; Pl-4, Fig. F.). In an ental view of the mouth-parts of *Heliothrips haemorrhoidalis* (Fig. F) a pair of fine, needle-like structures can be seen. These piercing organs (m.s.) are connected to the ental surface of the caudal arms (c.a.) of the head-capsule at the point of the invaginations (i) which can be seen on the ectal surface. These connections are of a ball and socket nature and thus permit the short, heavy, basal pieces to move considerably. Each needle-like piercing structure consists of three parts. The short basal piece just described extends away from the apex of

the mouth-cone when the mouth-parts are retracted and at its distal end the long, seta-like, piercing portion is connected by a ball and socket joint. The basal portion of the seta-like, piercing portion is swollen, while the distal portion is small, solidly chitinized and sharply pointed. The basal, swollen portion has a distinct suture near its middle. Altogether then each of the paired, piercing organs is composed of three parts and by means of the two joints in each, they may be straightened out and thus extruded from the mouth-cone. For convenience of description in the following discussions and in the drawings, the paired, piercing organs will be called mandibular setae.

In an ento-ventral view of the head and mouth-parts of *Cephalothrips yuccae* (Fig. 5) a pair of piercing structures, mandibular setae (m.s.) can be seen that correspond to those just described in *H. haemorrhoidalis*. Without much question these paired parts in *C. yuccae* are homologous with those in *H. haemorrhoidalis* for in each suborder they consist of three parts and their connection with the head-capsule is morphologically the same. The mandibular setae (m.s.) of *C. yuccae* are exceedingly long as they extend forward into the elongated head to the region of the compound eyes, where they turn back and go to the mouth-cone. Each mandibular seta consists of three parts, as in *H. haemorrhoidalis*. The basal piece is stout, considerably elongated and has on its mesal margin a distinct, knob-like structure (See Internal Head-skeleton for discussion on this adaptation.) The length of the basal piece in *C. yuccae* is much

longer than that of *H. haemorrhoidalis* but its length in proportion to that of the remainder of the mandibular seta (m.s.) is no longer than in *H. haemorrhoidalis*. Both ends of this basal piece have distinct ball and socket joints which permits the mandibular seta to function. The enlarged portion beyond the distal end of the basal part is comparatively short and is separated from the very long, flexible, needle-shaped piece by a distinct suture. In respect to structure we see that the two paired, piercing organs (m.s.) are structurally homologous in the two suborders.

The relation of the mandibular setae to the internal head-skeleton may at first glance seem to be entirely different in the two suborders. (For the relation of the mandibular setae (m.s.) to the mesal strips (x) in *C. yuccae* see discussion of Internal Head-skeleton). As was seen in *H. haemorrhoidalis* (Fig. F.) the paired piercing organs connect with the ental surface of the caudal arms (c.a.) of the head-capsule at the point of the invaginations (i). In *C. yuccae* the invaginations are still located in the same relative position as in *H. haemorrhoidalis* but the mandibular setae (m.s.) do not arise from the ental surface of the caudal arms of the head-capsule. The mandibular setae arise from ball and socket joints which are situated at the cephalic ends (w-1) of the cephalic, extending thickening (w) as described for the internal head-skeleton of *C. yuccae*. F. Muir and J. C. Kershaw call these elevated, club-shaped structures, mandibular pillars. The connection of the man-

dibular setae to the mandibular pillars is almost directly cephalad of the caudal arms and at a considerable distance from the ectal invaginations on the caudal arms of the head-capsule.

This peculiar adaptation on the part of *C. yuccae* may be explained by the fact that in the excessive development of the paired piercing organs, the connections with the head-capsule necessarily moved cephalad in order that the long, mandibular setae might function. Even tho the exact connection of the mandibular setae with the head-capsule is not near the invaginations of the caudal arms, the existence of the thickenings (w) which lead to the present connection indicates that morphologically the paired organs are still associated with the invaginations on the caudal arms. Thus far, it has been shown that the invaginations on the two caudal arms are associated in both suborders with the paired, piercing organs. This fact further supports the statement that in the two suborders the paired, piercing organs are homologous.

H. Garman in his work on *Limothrips cerearium*, a species of *Terebrantia*, decided that the paired, piercing organs were portions of the maxillae. In his dissection of the mouth-parts he found that the piercing organs are attached to the cephalic end of the maxillary sclerites. This connection at times is difficult to make out but in stained, dissected material or in stained, lateral views of whole mounts it can be seen that the basal piece of a paired, piercing organ (m.s.) connects with the ental surface of the caudal arms (c.a.) near the invaginations. In all specimens and species examined of *Terebrantia* the connections

were always with the ental surface of the caudal arms. This fact eliminates the force of H. Garman's argument that the paired piercing organs are portions of the maxillae.

F. Muir and J. C. Kershaw interpret the paired, piercing organs of *Tubulifera* as mandibles. By means of their observations on the mouth-parts of *Hemiptera* they have worked out the homology between the mandibles of *Hemiptera* and those of *Tubulifera*. The significance of this relation I am not satisfied with. However, on the basis of their maxillary seta interpretation (See Maxillae) along with other evidence I believe their interpretation is more nearly proved correct than H. Garman's interpretation. Consequently, their interpretation has been adopted and the homologous parts in the two suborders have been designated accordingly.

As mentioned in the discussion of the internal head-skeleton, the mandibles and maxillae are always associated with specific, internal head structures (arms of the tentorium) and the invaginations on the ectal surface of the head-capsule. Mandibles are always associated with the invaginations of the anterior arms and maxillae with the invaginations of the posterior arms. In all thrips examined two pairs of invaginations have been found on the head-capsule and without question the respective pairs are homologous thruout all Thysanoptera. Furthermore, it has been noted that the paired, piercing organs are always associated with the invaginations on the caudal arms of the head-capsule. Thus far, these relations have been observed but I feel that they

are not as yet complete, for in all insects I have examined three pairs of invaginations always occur and furthermore the above mentioned association of the mandibles and maxillae with the invaginations of the arms of the tentorium always exist; therefore I am sure such relations must exist in Thysanoptera. When such relations are fully understood, then the interpretation of the piercing organs will be correctly answered.

Pharynx,)Pl-3, Fig. 7; Pl-4, Fig. F,G,H,I, 9,10,11 and 12; Pl-5, Fig. J and 13). - In dissecting specimens of Cephalothrips yuccae that had been boiled in a 10 per cent solution of potassium hydroxide, a peculiar, short, heavily chitinized, ham-shaped piece was found lying beneath the clypeus. On examination of other species of thrips I found that this piece existed in all cases. For a long time the structure and function of this piece (p) puzzled me. However, as soon as sectioned and stained material was resorted to, its real structure and function was learned. The whole affair is a structural modification of the alimentary canal which aids in sucking nourishment into the oesophagus.

In general this chitinized, ham-shaped piece (p) is slightly longer than the labium and is centrally located in the mouth-cone (Fig. F,J,7 and 13). Cross sections of the mouth-cone show that it is firmly attached at its ventral end with the internal, tentorial structures as mentioned in the discussion of the tentorium. The pharynx also has lateral extensions (l.e.) that are trough-like and along the cephalic sides of which the pierc-

ing mouth-parts slide (Fig. 11). These piercing mouth-parts hold the pharynx in a fixed position so that when the large muscles (d.m.) that are attached to the cephalic side contract the whole pharynx does not move. On account of the asymmetry of the piercing organs a corresponding asymmetry exists in the pharynx. On the side (left) of the functional maxillary seta, two lateral extensions (l.e.) of the pharynx exist, one caudad of the maxillary seta (mx.s.) and the other caudad of the left mandibular seta (m.s.) while only one lateral extension is present on the right side caudad of the right mandibular seta (m.s.). In *H. haemorrhoidalis* especially (Fig. G and I), the absence on the right side of the distinct wide sheath (l.e.) over which the maxillary seta (mx.s.) of the left side passes is very noticeable. By means of material sectioned in three planes (frontal, sagittal and transverse) one can see that a centrally located canal (1) runs thru the entire length of this ham-shaped piece and that this canal continues dorsad of the chitinized structure as the oesophagus (oe.). Consequently, on account of the relation of this chitinized piece to the alimentary canal this structure is homologous with the pharynx of other insects. In general the pharynx consist of two distinct portions in respect to size and shape. The ventral half of the pharynx is a very small, chitinized tube which opens within the ental groove of the labrum, while the dorsal half widens out into a broad, thick area. Within this enlarged part of the pharynx a distinct sucking apparatus can be seen. In all thrips examined an organ corresponding to the

above description has been found. In the suborder Terebrantia this particular structure (p) is more generalized than in the suborder Tubulifera. For this reason the Terebrantia will be described first.

The pharynx of *Heliothrips haemorrhoidalis* (Pl-4, Fig. F, G, H and I; Pl-5, Fig. J) is most easily seen in dorsal views of the head and mouth-parts after the labrum has been removed (Fig. F). By careful dissection one can remove the pharynx and thus see it from all sides. From a cephalic or caudal view (Fig. G and I) its two distinct regions remind one of a circular leaf connected with a petiole. The ventral half is the small, chitinized tube, already mentioned, while in the dorsal half the tube widens out to such an extent that its width is fully equal to the length of the dorsal half. In a lateral view (Fig. H.) the dorsal half does not widen to as great an extent and the enlargement is principally the caudal bulging or convexity in the dorsal region. The entire pharynx, so far as can be made out, consists of one solid piece except for a broad, plate-like structure (c.m.) located in the concavity on the cephalic side of the enlarged part.

Pharynges (p) in general resemble gourd dippers which have had almost one half of their enlarged portions removed and in these cavities are placed a flat or concave piece (c.m.) whose entire margin is connected with the margin of the concave opening by a flexible membrane (me.). The pharynx of *H. haemorrhoidalis* in general corresponds to this condition. A distinct lumen runs thru the entire pharynx and opens at the dorsal and ventral ends. In a caudal view of the pharynx (Fig. I) of *H. haemorrhoidalis* a

distinct, truncate notch occurs at its dorsal end and just ventrad of this notch is located a pair of minute, circular openings (d). On the left margin of this pharynx a very, distinct, broad flange can be seen over which the functional, asymmetrical, maxillary seta (mx.s.) passes.

In a sagittal section thru the meson of the pharynx one can best see the structure of the pharynx. In such a section (Pl-5, Fig. J) we see that the ventral, tubular portion is a tube, for a distinct lumen (l) runs thru its entire length and as far as can be determined the tube is made up of one piece. In the region of the dorsal half the tube thickens and bulges caudad. Ectally there is a distinct convexity while the ental surface is concave. Into this concavity the concave plate (c.m.) of the cephalic side fits. This plate is more or less membranous and is connected on all its edges to the margin of the concavity by means of an elastic membrane. The plate (c.m.) and its connection (me.) is indicated in (Fig. G. and J.) by stippling. Stained sections show that the plate and its connection is somewhat more membranous than the remainder of the pharynx. To the ectal surface of this plate large muscles (d.m.) are attached. The larger muscles (v.d.m.) connect with the ventral portion of the plate while only two small strands (d.d.m.) connect in the region of the dorsal half. Of the large muscles, the larger group in particular has a chitinized tendon (ch.) while the remainder fray out into a number of small tendons before attaching themselves to the plate. The muscles just described attach themselves to the ventral and cephalic areas of the head-capsule

and in their cephalic extension occupy a large part of the space in the ventral region of the head.

The function of these muscles (d.m.) is to dilate the pharynx and thus they may be termed the dilators of the pharynx. When the large muscles contract the plate to which the muscles are attached is pulled cephalad and out of its resting position and in this way the pharynx is dilated. During this dilation a partial vacuum is formed and thus the plant juices are sucked into this concavity. While this first response is taking place the lumen of the oesophagus at the dorsal end of the pharynx must be closed. Thus far no indications of muscles have been found that would keep this closed. The passage at this point is very minute and thus the pressure would not be very great. After the contraction of the muscles, the plate (c.m.) must be brought back into its normal position by its own elastic nature for no muscles were found that could bring the plate back into its resting position. As the plate responds to its elastic condition after the relaxation of the muscles, pressure is brought to bear upon the food in the cavity and at this point the opening to the oesophagus is relaxed and thru this opening a portion of the liquid nourishment passes into the oesophagus. The above description of the way in which suction takes place is merely an inference based upon the structural arrangement. However, the important point is, that the large muscles dilate the pharynx and such dilation results in suction.

So far as I have been able to ascertain the two small, cir-

cular openings (d) on the dorsal end of the caudal aspect of the pharynx are the openings for the salivary ducts (See later discussion on Salivary Glands.)

In general the pharyngeal structure of *Cephalothrips yuccae* (Pl-3, Fig. 7; Pl-4, Fig. 9, 10, 11 and 12; Pl-5, Fig. 13), - corresponds with that of *H. haemorrhoidalis*. A few detailed structures show, however, a greater degree of specialization and these will be treated of in particular. In the first place, the pharynx of *C. yuccae* is not actually as large as the pharynx of *H. haemorrhoidalis* even tho the head of *C. yuccae* is much larger than that of *H. haemorrhoidalis*. The pharynx is about as long as the labium and is strikingly ham-shaped or gourd-shaped. The ventral end is tube-like, while the dorsal half, from a cephalic or lateral aspect (Fig. 9 and 12), has a width about two-thirds that of the length of the enlarged portion.

In a sagittal view (Fig. 13) it can be seen that the parts hold the same relation as those in *H. haemorrhoidalis*. The caudal piece of which the tube is a portion of, is a continuous one and has no distinct caudal bulge in the enlarged region. Two minute circular openings (d) occur on the caudal aspect in the ventral half of the enlarged portion (See Salivary Glands). The dorsal area of the pharynx of *C. yuccae* is bulged cephalad (Fig. 12) just ventrad of the location of the plate. In a sagittal (Fig. 12) section this bulge of the dorsal end is very distinct. Thus far a few marked differences between the pharynx of *C. yuccae* and that of *H. haemorrhoidalis* have been noted

but the most striking difference exists in the structure of the plate (c.m.) which is located in the cephalic concavity of the enlarged portion and the muscle arrangements on this plate.

The plate (Fig. 9, 11 and 12) in *C. yuccae* is of an inverted T-shape. The cross of the T corresponds to the plate (c.m.) which is submerged (Fig. 11) in the concavity and is attached on all sides to the margin of the concavity by a somewhat membranous, elastic tissue. In stained, transverse or sagittal sections the plate and its connections show a light blue stain, if stained with Ehrlich's acid haematoxylin. This indicates that the protoplasmic content is high. The stem of the T corresponds to an elevated chitinous ridge on the meson of the plate. This ridge (r.) is swollen at its distal edge and in a lateral view (Fig. 12) is exposed just a trifle when the plate is submerged. To the ventral and dorsal ends of this ridge muscles are connected. The ventral muscles or ventral dilators of the pharynx (v.d.m.) are longer, larger, and composed of more strands than the dorsal dilators of the pharynx (d.d.m.). The ventral dilators are not directly attached to the mesal ridge of the plate but they attach themselves to a distinct chitinized piece (ch.) that extends cephalad from the ventral end of the mesal ridge (r.) of the plate. The majority of the strands of the ventral dilators of the pharynx connect with the cephalic end of the head-capsule in the region of the vertex. The dorsal dilators of the pharynx (d.d.m.) connect directly with the dorsal end of the ridge and are much shorter and smaller than the ventral dilat-

ors (v.d.m.). Their attachment (d.d.m.) to the head-capsule is in the caudo-ventral area (fr.) just cephalad of the clypeus. This definite arrangement of muscles was not found in *H. haemorrhoidalis* but possibly the somewhat ventral attachment to the plate of the large dilators (v.d.m -?) and the two small strands (d.d.m -?) that connect with the plate in the dorsal half might suggest the beginnings of such an arrangement as we find in *C. yuccae*.

The dilating muscles of both species in stained sagittal sections show their nuclei very distinctly and their cross striated character. The striations in *C. yuccae* are very close, while in *H. haemorrhoidalis* lighter colored, transverse bands occur at frequent intervals.

On account of the above structural modifications in *C. yuccae*, possibly a more successful sucking apparatus has been developed than that existing in the more generalized *H. haemorrhoidalis*. I believe the manner in which suction comes about in *C. yuccae* to be on the same plan as occurs in *H. haemorrhoidalis*. When suction is taking place the most logical inference is that the dorsal end of the plate (c.m.) is more or less fixed and acts as a hinge, while the ventral end of the plate is being dilated by the large, ventral dilators (v.d.m.) of the pharynx. As the ventral end is dilated to the length of its membranous extension a partial vacuum is formed in the pharyngeal cavity and into this cavity is then sucked the liquid food in which the apex of the head cone is immersed. It should be here men-



tioned that a distinct kink or notch occurs in the oesophagus at the small beginning of the oesophagus. Such an adaption will naturally aid in keeping closed the oesophagus while the first step of the process of sucking is taking place. As the pharyngeal cavity becomes filled the large, ventral muscles relax and the elastic nature of the plate then brings to bear pressure upon the endosed liquid food. At the same time the dorsal dilator of the pharynx raises the dorsal end of the plate and the opening to the oesophagus being relaxed the food is forced dorsad into the dorsal part of the pharynx and on into the cesophagus. Such is a possible way in which food may be taken into the alimentary canal.

Salivary Ducts and Glands (Pl-5, Fig. J and 13; Pl-4, Fig. H and 12.). - The discussion of the salivary glands in the description of the pharynx was omitted in order that the ducts and glands of the two species might be considered in one place. In the description of the caudal views of the pharynx a minute pair of circular openings, (d) was noted on each pharynx. As far as I have been able to ascertain these are the openings for the right and left salivary ducts.

In sagittal sections it has not been possible to trace in any one section a complete connection of a gland with these paired openings. The best I have seen as yet is the existence in *C. yuccae* of a very short tube extending dorsad from one of these openings almost to the commissures, while in other sections I have found a similar tube dorsad of the commissures that ex-

tend caudad and connect with the salivary glands that lie laterad and somewhat ventrad of the alimentary canal. This same kind of evidence has been found in *H. haemorrhoidalis* and I feel warranted in saying that these are ducts (s.d.) of the salivary glands and that the glands (s.g.) pour their secretions into the pharyngeal cavity thru the circular openings (d) on the caudal aspect of the pharynx. Assuming this to be true the salivary ducts run parallel with the oesophagus back into the thoracic region where in the case of *H. haemorrhoidalis* the ducts connect with the branched salivary glands (s.q.) that lie laterad and somewhat dorsad of the alimentary canal. In *C. yuccae* the ducts hold the same relative position and connect with a simple, straight, glandular tube (s.g.) that runs parallel with the alimentary canal and is located laterad and ventrad of it. As the ducts run parallel with the oesophagus in the region of the commissures it should have been mentioned that the ducts (s.d.) are located laterad of the two commissures that connect the supraoesophageal ganglion and the suboesophageal ganglion.

If the salivary secretion is poured into the pharyngeal cavity it can become thoroly mixed with the liquid food before the food is passed into the oesophagus. Possibly the salivary secretion is even forced out into the puncture made by the piercing organs. This fact is here mentioned because it may help to explain the fact the when thrips puncture colored flowers and green leaves a colorless or yellowish area forms about the puncture. This bleaching may in part be due to the action of

the salivary secretion upon the plant tissue about the puncture. It is hoped that in the further sectioning of material more definite evidence may be found in regard to the connection of the salivary glands.

With the observations made thus far, the brief description given above of the pharynx, salivary glands, etc. brings into relation the structure and function of these parts in the two suborders of Thysanoptera. As to the homology of these parts with similar organs of Hemiptera and other insects I do not wish to make any definite statements in this preliminary report. However, on the few comparative observations that have been made I feel that the parts found in Thysanoptera will readily homologise with the corresponding structures in other insects. In the sectioned and stained material used for observation many interesting parts have been made clear and I expect to do more work with other forms along this line.

As seen in the foregoing discussion many points of observation need still to be made, likewise, in the region of the pharynx a more detailed study needs to be made for a peculiar structure exists just caudad of the pharynx near its ventral end. This structure shows particularly well in sagittal sections of *H. haemorrhoidalis*. As to the exact nature of this structure nothing definite can be said but it is very suggestive of the structure found in Hemiptera called the salivary syringe (Muir and Zershaw). Other interesting internal structures can be seen very readily in sectioned material. Of these I cannot refrain from

mentioning a few important ones. In Thysanoptera the ganglia (Fig. 5 and 13) of the nervous system are exceedingly large in comparison with the ganglia of other insects. In sagittal sections of *C. yuccae* a few exceedingly large, globular nucleated cells (Fig. 13 - oy.) exist about the oesophagus just dorsad of the place where the oesophagus passes between the two commissures of the supraoesophageal ganglion (supra.) and the suboesophageal ganglion (sub.). These resemble in a marked degree oenocytes found in other insects.

VII. CONCLUSIONS

This paper is but a preliminary report upon the ectal skeleton of Thysanoptera. As the subject indicates, the study of the morphology of the head and mouth-parts only has been attempted. In this paper the whole investigation narrows down to a comparative discussion of the head and mouth-parts of the two suborders of Thysanoptera. *Cephalothrips yuccae* has been used as a type of Tubulifera and *Heliothrips haemorrhoidalis* as a type of Terebrantia. Of the two suborders, Terebrantia is the more generalized and from this view point the parts have been discussed. In respect to the fixed parts of the head the following points need emphasis.

In *Terebrantia* the caudo-ventral margin of the head-capsule is decidedly more asymmetrical than that of *Tubulifera*.

All the head-capsules of *Thysanoptera* examined had more or less prominent caudal arms (c.a.) but those found in *Tubulifera* are much more pronounced than the caudal arms found in *Terebrantia*.

The clypeus and labrum are very distinct and similar in both suborders. The clypeus is the large, mesal, triangular portion of the mouth-cone, while the labrum is the small, convex, concave piece which fits about the left, maxillary seta (mx.s.) as it is extruded from the mouth-cone. In *Tubulifera* the clypeus has a distinct notch on its left, lateral margin, while the clypeus of *Terebrantia* is a decidedly, asymmetrical triangle.

In the development of the internal head-skeleton the most striking differences exist in the two suborders. In the suborder *Tubulifera* long, mesal, tentorial arms (x,y, x-1, x-2 and x-3) exist, which help to support and guide the paired, piercing organs. The only piece in *Terebrantia* that can be homologous with the internal mouth-part-supports of *Tubulifera* is the y-shaped piece (y) found caudad of the pharynx. The internal thickenings found on the caudo-ventral area of the head-capsule are decidedly similar in the two suborders. In *Terebrantia* the thickenings on the left are three branched (z-1, z-2, and v.), while on the right there are only two branches (z-1, and z-2), the cephalic branch (v) being lost. In *Tubulifera* there are three branches on both sides (z-1, z-2, and w.). Of the above branches the caudal and middle branches (z-1 and z-2)

are homologous in the two suborders. In the Tubulifera the pair of cephalic branches (w) are merely cephalic growths of the caudal branch (z-2) brought about as adaptations necessary for the functioning of the excessively large mandibular setae. In Terebrantia the one left cephalic branch is an indication of a generalized condition for it connects the thickenings about the mouth-cone (z) with the distinct invaginations found on the ventral side of the head. On the ectal surface of the head-capsule two pairs of distinct invaginations (i) occur on all species examined. One pair is always located caudad of the meso-caudal angles of the compound eyes and the other pair is always near the distal end of the caudal arms (c.a.) of the head-capsule. The respective pairs of invaginations are without question homologous throughout all thrips. These invaginations are associated with their respective internal head structures, consequently, when the internal head-skeleton has been worked out then these invaginations may be correctly designated. Furthermore, as mentioned before certain mouth-parts are always associated with certain internal head structures and invaginations, therefore, when the internal head-skeleton is correctly interpreted and the relation of the mouth-parts to the tentorial structures and invaginations has been decided upon, then light will be cast upon the interpretation of the questionable mouth-parts.

Of the movable parts of the head no striking variations occur in respect to the antennae or labium.

In taking up mandibles and maxillae at this point it would make the concluding statements too detailed to review the dis-

cussion of these parts as we did with the internal head-skeleton, consequently only the broad, general conclusions will be mentioned.

The most important conclusion reached is that in the two suborders the paired piercing organs (m.s.) are homologous and the asymmetrical, piercing organs (mx.s.) are homologous. This homology is based upon a comparative study of the structure and position of the respective parts. This conclusion does not agree with the suggestion offered by F. Muir and J. C. Kershaw, that possibly in the two suborders the left asymmetrical mouth-seta of *Tubulifera* is a part of the maxillae, while in *Terebrantia* it is a mandible.

In this preliminary report no definite conclusions can be offered in respect to the correct interpretation of the piercing organs. All that can at present be said is that the evidence for the interpretation offered by F. Muir and J. C. Kershaw is possibly more conclusive than that offered by H. Garman. F. Muir and J. C. Kershaw consider the asymmetrical, piercing organs (m.s.) as portions of the maxillae and the paired, piercing organs as mandibles. Personally, I do not consider the evidence advanced by either H. Garman or F. Muir and J. C. Kershaw sufficient to prove either of their positions as correct. Especially is this true when both suborders are taken into consideration. In this investigation I am reasonably sure that the true interpretation can be reached by a thoro study of the relations of the mouth-parts with the internal head-skeleton.

Homologizing the mouth-parts and internal head-skeleton of Thysanoptera with like parts in generalized Hemiptera should also aid in reaching the true interpretation.

In regard to the pharynx it should be mentioned that a distinct pharynx was found connecting the oesophagus with the mouth opening. The pharynx is so constructed as to aid in sucking in the food. Connected to the pharynx are large, dilating muscles and into the caudal aspect of the pharynx a pair of salivary ducts enter. These ducts lead back into the thorax and connect with salivary glands.

VIII. EXPLANATION OF PLATES

Plate 1

- Fig. 1. Ventral view of the head of *Cephalothrips yuccae*.
Fig. 2. Dorsal view of the head-capsule of *Cephalothrips yuccae*.
Fig. 3. Lateral view of the left side of the head of *Cephalothrips yuccae*.
Fig. 4. Antenna of *Cephalothrips yuccae*.

Plate 2

- Fig. A. Ventral view of the head of *Heliothrips haemorrhoidalis*.
Fig. B. Dorsal view of the head-capsule of *Heliothrips haemorrhoidalis*.
Fig. C. Lateral view of the left side of the head of *Heliothrips haemorrhoidalis*.
Fig. D. Lateral view of the right side of the head of *Heliothrips haemorrhoidalis*.
Fig. E. Antenna of *Heliothrips haemorrhoidalis*.

Plate 3

- Fig. 5. Ental view of the ventral and lateral portions of the head-capsule and mouth-parts of *Cephalothrips yuccae*. Pharynx and y-shaped internal head-skeleton removed.
Fig. 6. Ental view of the left maxillary sclerite.
Fig. 7. Ental view of the ventral and lateral areas of the mouth-cone. Labium and piercing organs removed.

Fig. 8. Ental view of the right maxillary sclerite.

Plate 4

Fig. F. Ental view of the ventral and lateral portions of the head-capsule and mouth-parts of *Heliothrips haemorrhoidalis*. Labium removed.

Fig. G. Cephalic view of the pharynx of *Heliothrips haemorrhoidalis*.

Fig. H. Lateral view of the pharynx of *Heliothrips haemorrhoidalis*.

Fig. I. Caudal view of the pharynx of *Heliothrips haemorrhoidalis*.

Fig. 9. Cephalic view of the pharynx of *Cephalothrips yuccae*.

Fig. 10. Caudal view of the pharynx of *Cephalothrips yuccae*.

Fig. 11. Transverse section of the pharynx of *Cephalothrips yuccae* thru line x - y in Fig. 12.

Fig. 12. Lateral view of the pharynx of *Cephalothrips yuccae*.

Plate 5

Fig. J. Sagittal section of the head and part of the prothorax of *Heliothrips haemorrhoidalis*.

Fig. 13. Sagittal section of the head and part of the prothorax of *Cephalothrips yuccae*.

Fig. K. Caudal view of the labium of *Heliothrips haemorrhoidalis*.

Fig. 14. Caudal view of the labium of *Cephalothrips yuccae*.

VIII. LIST OF ABBREVIATIONS

- ant. Antenna.
c. Clypeus.
c.a. Caudal arms of the head-capsule.
ch. Chitinous structure.
c.l. Clypeo-labral suture.
c.m. Chitinous and membranous plate of the pharynx.
d. Opening thru the caudal aspect of the pharynx for the salivary duct.
d.d.m. Dorsal dilating muscle of the pharynx.
d.m. Dilating muscles of the pharynx.
f. Fold in the clypeus located at the point where the mouth-cone turns ventrad and projects at right angles to the head.
f.c. Fronto-clypeal suture.
fr. Front of the head-capsule.
g. Gena.
h.c. Head-capsule.
i. Invaginations of the arms of the tentorium.
l. Lumen-Canal in the oesophagus and pharynx.
lb. Labium.
lb. pl. Labial palpus.
l.e. Lateral extensions on the pharynx.
l.m.x. Left maxillary sclerite.
lr. Labrum.

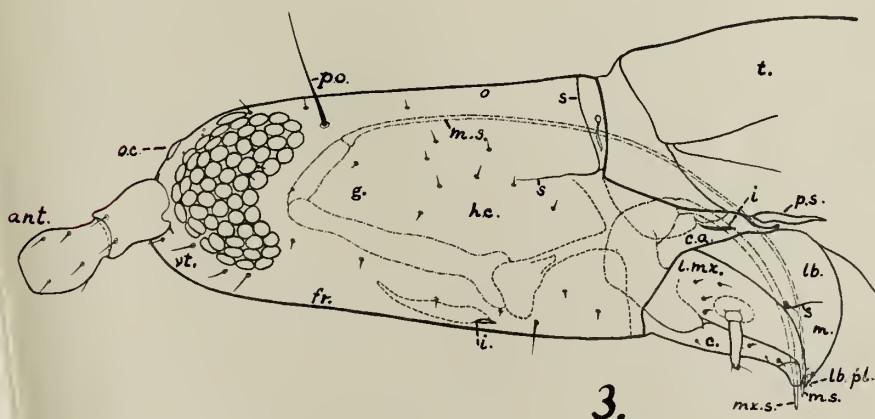
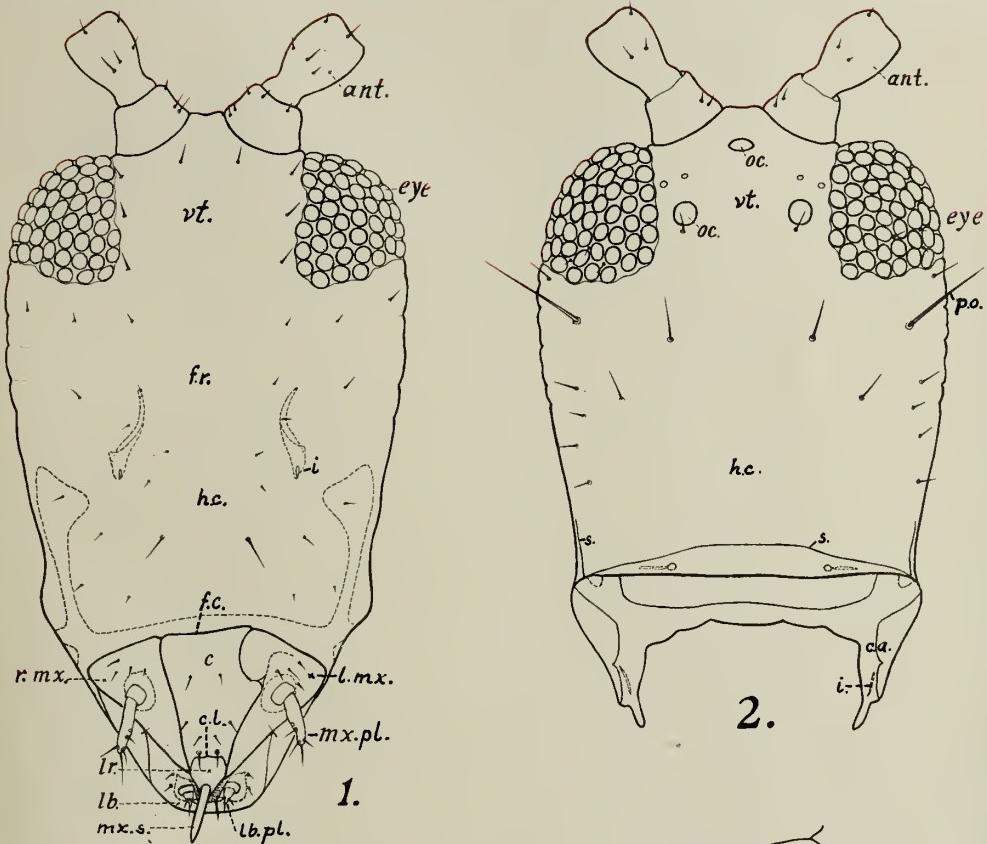
- m. Mentum.
- me. Areas that are membranous.
- m.s. Mandibular seta(e) or elongated mandibles.
- mx.pl. Maxillary palpus.
- mx.s. Maxillary seta-Piercing organ arising from the left maxillary sclerite.
- o. Occiput of the head-capsule.
- oc. Ocellus.
- oe. Oesophagus.
- oy. Oenocytes.
- p. Pharynx.
- p.o. Postorbital setae.
- p.s. A prothoracic sclerite against which the acetabulum of the caudal arms fits.
- q. Conical projections on the ento-ventral surface of the head-capsule.
- r. Elevated ridge arising from the plate (c.m.) of the pharynx.
- ri. Reticulations on the ectal surface of the head of *H. haemorrhoidalis*.
- rt.mx. Right, maxillary sclerite.
- r.mx.s. Right, rudimentary, maxillary seta.
- s. Suture.
- s.c. Sense cones of the antennae.
- s.d. Salivary duct connecting salivary glands with the openings (d) in the pharynx.
- s.g. Salivary gland.

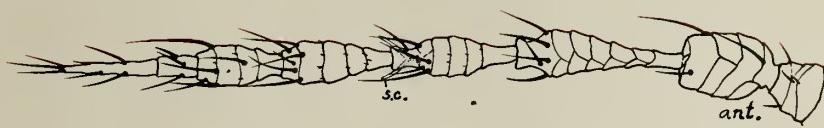
- s.m. Submentum.
- supra. Supraoesophageal ganglion.
- sub. Suboesophageal ganglion.
- t. Thorax.
- v. The single, left, cephalic branch of the thickening on the head-capsule of *H. haemorrhoidalis*.
- v.d.m. Ventral, dilating muscle of the pharynx.
- vt. Vertex of the head-capsule.
- w. Paired, cephalic branches of the thickening on the ventral surface of the head-capsule of *C. yuccae*.
- w-1. Enlarged cephalic endings of the paired, cephalic branches of *C. yuccae*. Ball and socket joints are located in these enlarged endings.
- x. Long, parallel, mesal strips in *C. yuccae* that aid in guiding the mandibular setae. (m.s.)
- x-1. The plate-like, cephalic ending of the mesal strips (x) in *C. yuccae*.
- x-2. Triangular plate in the mouth-cone from which the mesal strips (x) arise.
- x-3. Dorso-lateral arms extending dorso-laterad from the triangular plate (x-2) and solidly united with the lateral edges of the maxillary sclerite.
- y. A y-shaped piece located caudad of the small, ventral end of the pharynx.
- z. Thickening along the ventro-caudal margin on the ventral surface of the head-capsule.

z-1. The lateral extending branch of the thickening (z).

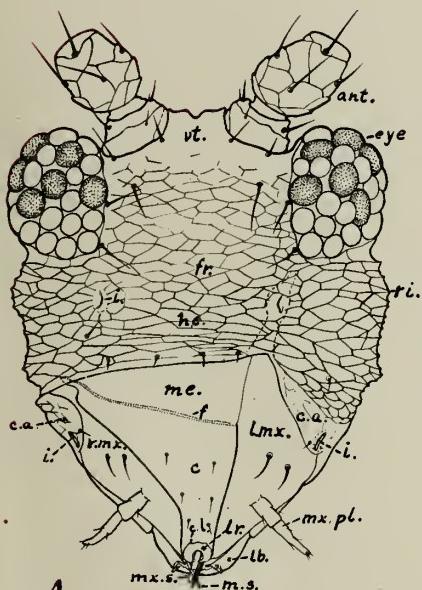
z-2 The caudal extending branch of the thickening (z).

This branch extends caudad on the ventral surface of the caudal arms (c.a.) and unites with the invagination (i) on the caudal arms.

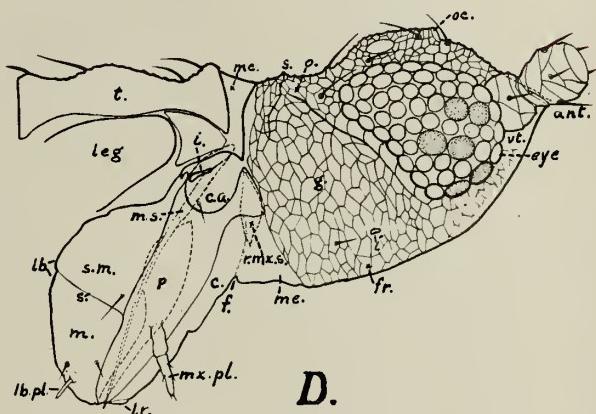




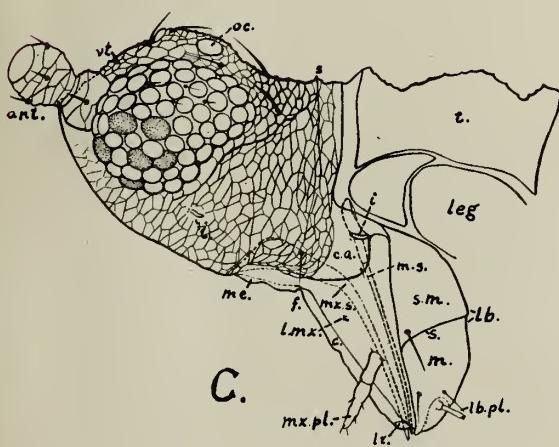
E.



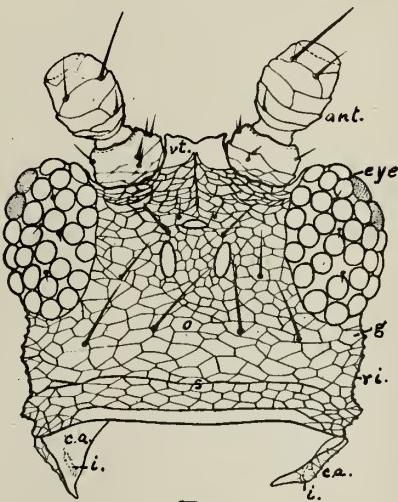
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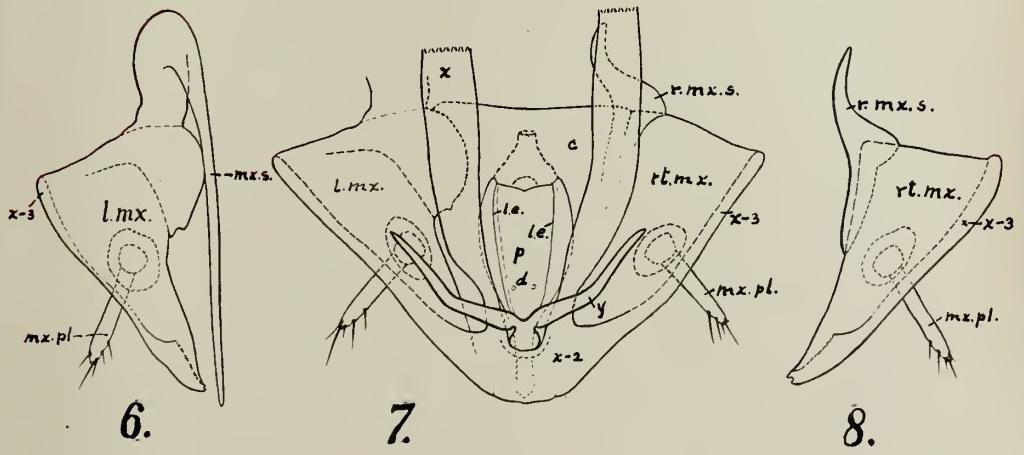
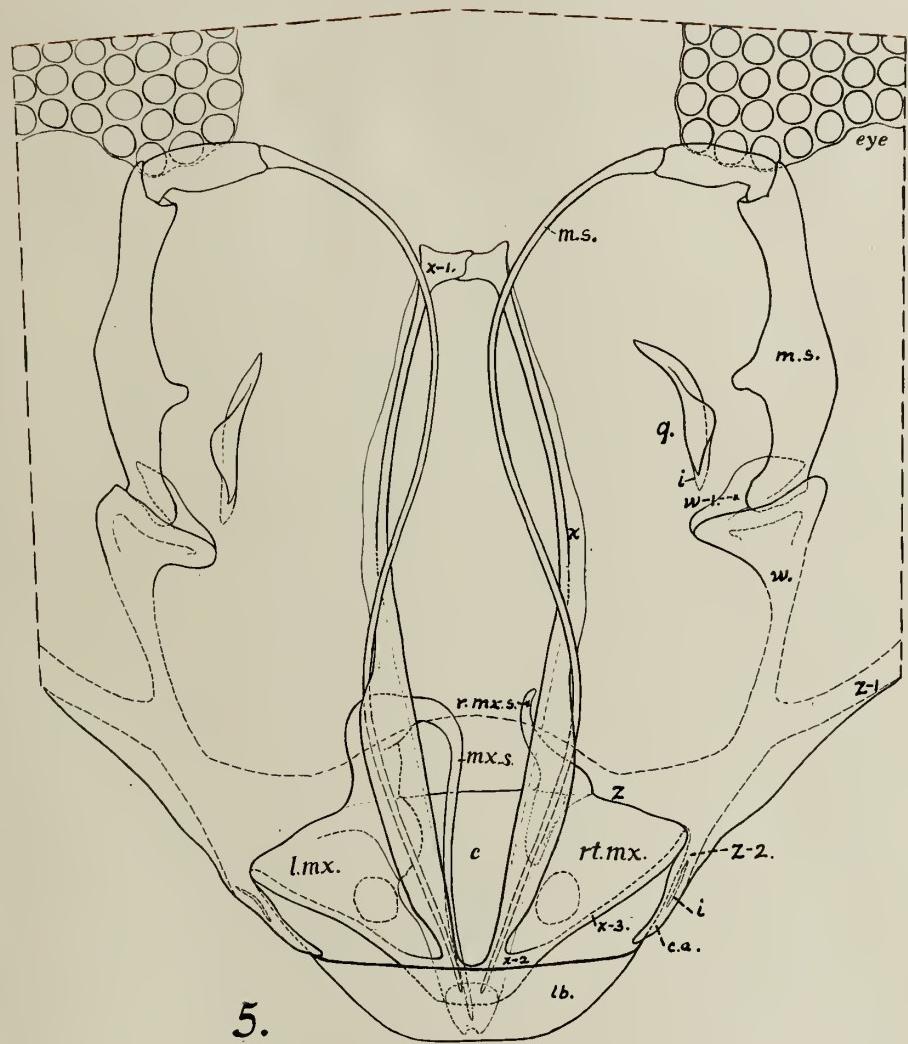
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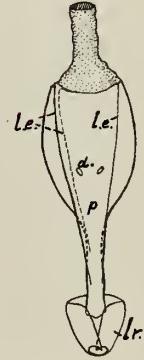
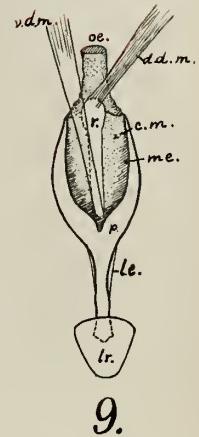
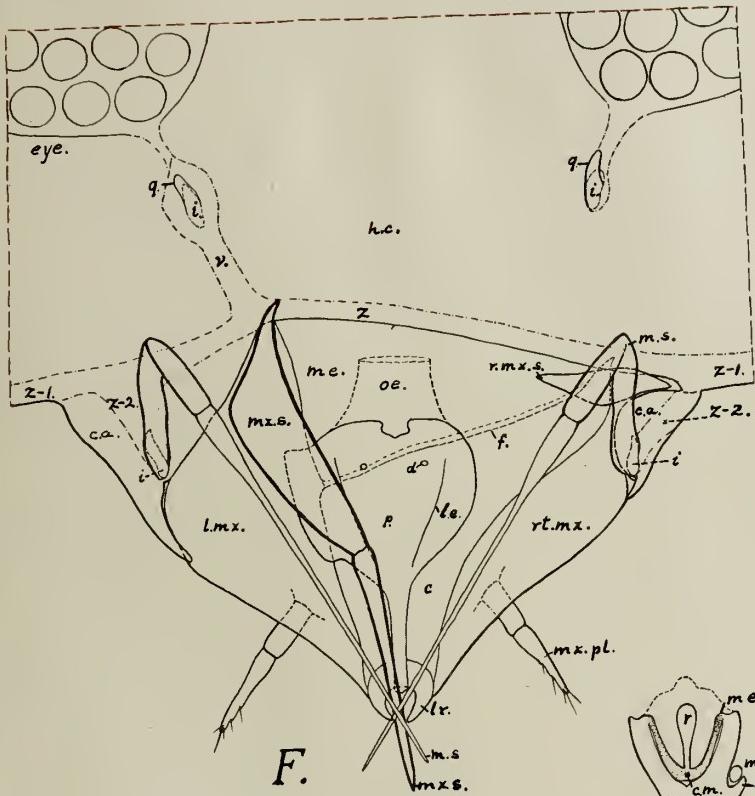


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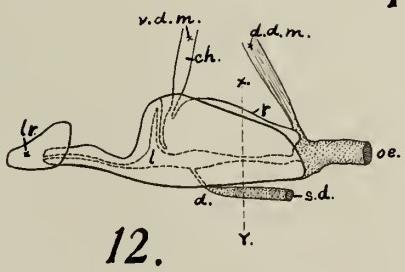
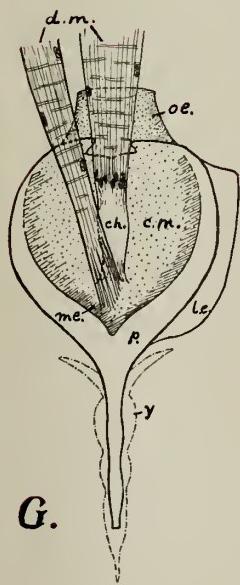


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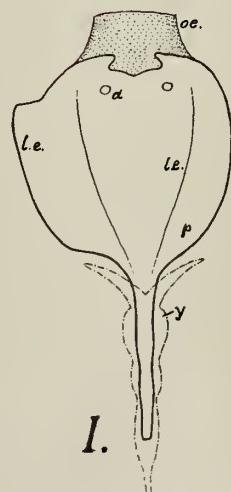




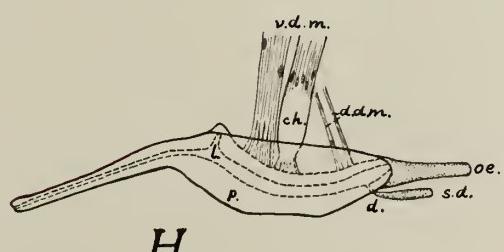
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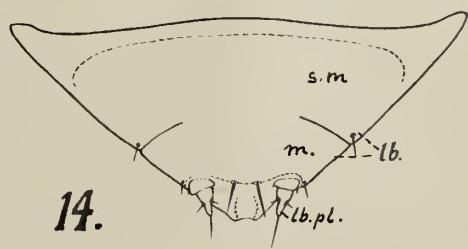
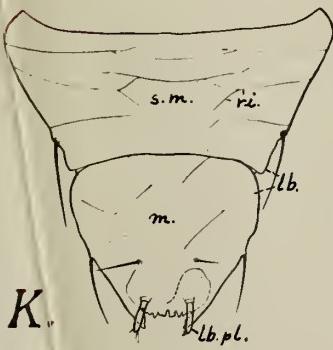
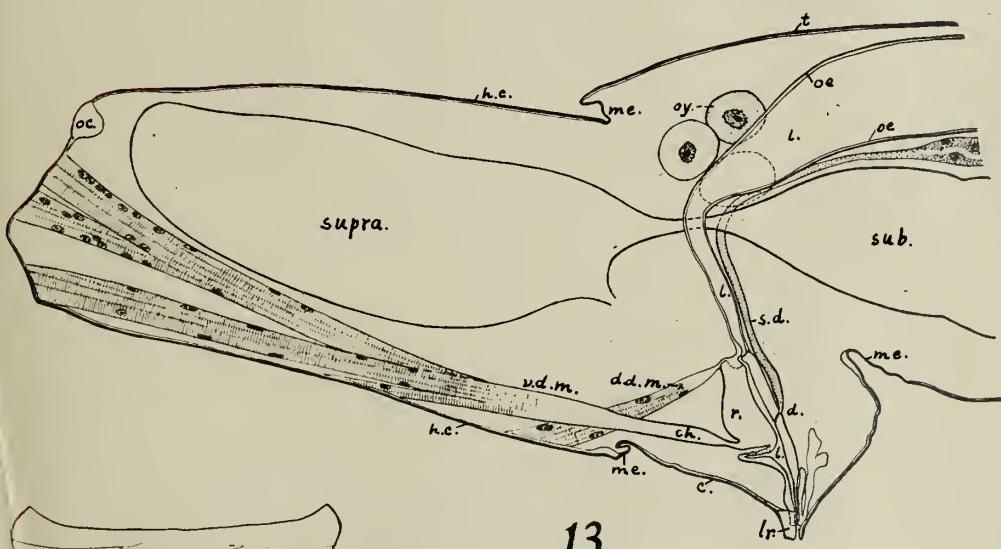
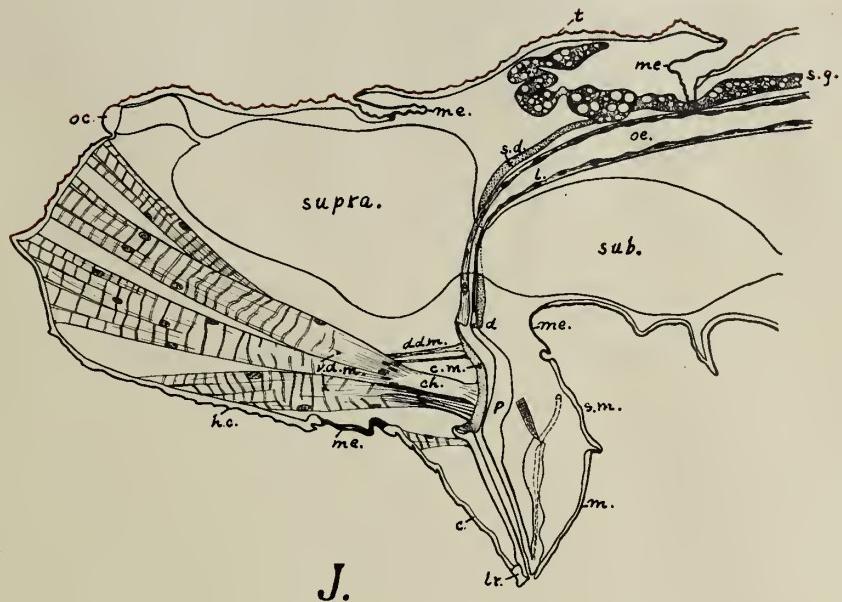
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I.



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